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Factors affecting smallholder farmers' adaptation to climate change through non-technological adjustments

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ABSTRACT

Smallholder farmers often employ inputs and practices they are traditionally well acquainted with to adapt to climate change. These types of adjustments, henceforth referred to as non-technological, are not only more feasible in the resource-constrained situation of smallholder farmers but also have a potential to significantly reduce the negative impact of climate change. However, a systematic study of these types of adaptations isolating them from technological ones is still lacking. While technological adaptations can benefit from the extensive literature on the adoption of agricultural technologies, non-technological adaptations still need further examination as one distinct group of adjustments. We hypothesize that this group of adaptations strongly depend on farmers' accumulated experience rather than financial resources and level of schooling. To test this hypothesis, we compared the determinants of changing planting date and changing crop type as non-technological adaptations, with the determinants of two technological adaptations: fertilizer use and rainwater harvesting. The investigation relied on a survey of 270 farm households in Semien Shewa Zone of Ethiopia. We used Wilcoxon Signed rank test and verified the importance of climate change in inducing the adjustments. A Multivariate probit model was then used to identify their determinants. Our hypothesis is supported by a positive relationship between farm experience and changing planting date, while fertilizer and rainwater harvesting showed a positive correlation with access to credit and level of schooling respectively. Our findings suggest that targeting non-technological farm-level adaptations through interventions focused on experience sharing can alone play an important role in reducing the impact of climate change in agriculture.

1. Introduction

Climate change is expected to significantly reduce agricultural productivity especially in tropical and subtropical regions (Rosenzweig and Parry, 1994; Knox et al., 2012; Jones and Thornton, 2003; Zhang et al., 2017). For instance, the loss of yield for major crops that account for 80% of production in Africa and South Asia may reach 8% by the middle of this century (Knox et al., 2012). Jones and Thornton (2003) estimate that a yield loss of 10% for maize alone in Africa and Latin America is equivalent to damages of $2 billion every year. In the absence of effective adaptation, such losses could translate into serious consequences for the welfare of a large number of people in the developing world (Nelson et al., 2009). IPCC (2014) defines adaptation as "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities". Adjustment here, is interpreted as any change made by a household in managing resources to respond to climate change and other drivers.

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Effective adjustment by farmers to changes in their environment including climate change may entail improved access to resources (Tol et al., 1998). According to the livelihood framework (Ellis, 2000; Scoones, 1998), farmers' ability to achieve their livelihood goals depends on their vulnerability context, livelihood assets, and transformation of structures and processes. The vulnerability context represents the trends, shocks and seasonality faced by farmers. A farmer needs to adapt to these external factors by employing assets or resources at his/her disposal. As per the framework, livelihood assets are divided in to five: human capital, social capital, physical capital, natural capital and financial capital. Improved access to these assets has been shown to influence the successful implementation of livelihood strategies (Smith et al., 2001; Babulo et al., 2008). However, the success of livelihood strategies also depends on access to institutions, infrastructural development, and policies, among others (De Haan and Zoomers, 2005; Ng'ang'a et al., 2016). These are known as 'structures and processes' within the framework, and can be viewed as resources, which are not owned or controlled by individual farmers.

A growing number of papers, especially those dealing with smallholder farmers in the developing world, have produced different lists of farm-level adaptations along with their resource needs or socio-economic and institutional determinants (Maddison, 2007; Deressa et al., 2011; Bryan et al., 2009; Alauddin and Sarker, 2014; Shikuku et al., 2017; Rahut and Ali, 2017). Farm-level adjustments, considered as adaptation responses by previous studies include: changing crop type, changing crop varieties, tree planting, soil and water conservation, changing planting date, fertilizer application and crop diversification (Maddison, 2007; Below et al., 2012; Deressa et al., 2011; Gbetibouo, 2009; Bradshaw et al.,; Tesfaye and Seifu, 2016; Ubisi Nomcebo et al., 2017). The studies also identified heterogeneous factors that affect adaptation which include among others: level of education, income, availability of labor, access to credit, and access to extension services (Fosu-Mensah et al., 2010; Bryan et al., 2009; Maddison, 2007; Deressa et al., 2009; Adimassu and Kessler, 2016; Ubisi Nomcebo et al., 2017).

However, earlier studies haven't produced a distinctive set of determinants that differentiate the adaptation process from the process of agricultural technology adoption that has shaped agricultural policy for decades. The importance of factors such as access to credit, level of schooling, and income has already been well established through the vast literature on agricultural technology adoption (Foster and Rosenzweig, 2010; Burton et al., 1999; CIMMYT, 1998; Doss and Morris, 2000). This has made the results of many studies in the past redundant in terms of suggesting additional interventions specific to adaptation. Exceptions include a few studies that single out the importance of information (Deressa et al., 2009; Kichamu et al., 2017), and farm experience (Maddison, 2007; Arunrat et al., 2017).

The problem results from the fact that prior studies (Maddison, 2007; Bryan et al., 2009) failed to systematically address the difference in the resource needs of technological and non-technological (as we define it here) adaptation strategies. The former take place using relatively new inputs such as fertilizer and improved seeds, and their determinants are likely to be similar to adjustments studied in the agricultural technology adoption literature. The latter, however, could potentially have distinct resource needs as they employ inputs or technologies that a community has become familiar with over generations. Examples include: changing planting date, changing crop mix, and crop diversification. Despite differences between the two categories, studies in the past attempted to produce a single set of determinants under a general heading of 'adaptation strategies to climate change'. For example, Maddison (2007) in their study on 11 African countries stated, "although experienced farmers are more likely to perceive climate change, it is educated farmers who are more likely to respond by making at least one adaptation". Similarly, Falco et al. (2011a) generalized that access to credit, access to extension and information are the key socio-economic factors that affect adaptation.

A separate examination of non-technological farm adjustments as one homogenous group can reveal a distinctive set of factors for farm-level adaptation to climate change. We hypothesize that these types of adjustments are relatively more influenced by farm experience than financial resources and level of schooling (see the following section for details). We tested our hypotheses based on a household survey in a study area in Semien Shewa Zone of Ethiopia. We examined the determinants of two non-technological adaptation strategies: changing planting date and changing crop type, along with two technological ones: rainwater harvesting and adoption of fertilizer. This study is one of the first to consider non-technological adjustments as potentially distinct types of adaptation responses. Such approach ensures that non-technological adjustments are not overshadowed by technological adjustments, whose determinants point in the same direction agricultural development programs have already been following: more credit, more access to market, and more education. Non-technological adaptations such as changing crop type and changing planting date, while being a low-cost policy option, can also significantly reduce the impact of climate change (Laux et al., 2010; Kurukulasuriya and Mendelsohn, 2008; Waha et al., 2013; Dharmarathna et al., 2014; Costinot et al., 2016),

2. Literature review

Farm adjustments that have been identified as adaptation responses to climate change are too diverse to allow the prescription of a single set of determinants. Despite this, several studies have attempted to do the same (Maddison, 2007; Oo et al., 2017). Such an approach could be linked to the legacy of the literature on agricultural technology adoption which usually treats technological adoptions as one group of adjustments that could be influenced by a closely related set of factors (Foster and Rosenzweig, 2010). In the adoption literature, the approach is valid because all the adjustments share the process of introducing a new input as a common denominator. When it comes to studying adaptation responses, however, this is not the case as adjustments could vary from a simple change in planting date, to adopting a new irrigation technology (Rahut and Ali, 2017; Yong, 2014; Alemayehu and Bewket, 2017).

One important way of categorizing farm adaptation responses with implications for their resource needs, is as transformative and incremental (Kates et al., 2012). The transformative ones are those that fundamentally change the characteristic of a farming system. An example could be shifting from mixed crop-livestock into agro-pastoral production system. Incremental adaptations, on the other hand, involve relatively marginal change, and are aimed at maintaining the existing state of the system (Wheeler et al., 2013). In

agriculture, such adaptations include changing planting date, changing crop type, adopting irrigation, etc. Transformative adaptation responses are distinguished by a larger scale of change, and can be considered distinct in terms of resource needs and outcome (Kates et al., 2012). The category of incremental, however, comprises of too diversified types of adjustments to allow any useful inference in the same way.

An alternative way of classifying adaptation options is as those in the intensive and extensive margin (Guo and Costello, 2009). Adjustments in the intensive margin involve continuous choice variables, where only the magnitudes of inputs are altered (Guo and Costello, 2009). For example, reallocating land amongst existing crops. Adaptation at the extensive margin arises when discrete changes are made (Guo and Costello, 2009), an example being adopting a new crop species or variety. The strength of this taxonomy is its identification of adjustments in the intensive margin as one important categories of adaptation. Yet, adjustments in the extensive margin can still be quite heterogeneous. As a case in point, adopting a traditional crop that is well known to a particular community is likely to be different from the case of adopting a new improved crop variety. For the former, simple information provision can facilitate the process, while for the latter more resource intensive interventions such as training programs and creating links to markets may be required.

Here, we propose classifying adaptation strategies as those that primarily use existing technologies (non-technological) and those that adopt new technologies (technological). The former are farm adjustments that employ technologies or inputs that have been traditionally used by a community for generations. Examples include changing crop type, changing planting date, changing harvesting date, crop rotation and crop diversification. Such adjustments primarily depend on local knowledge that accumulated over generations, and heavily rely on resources that are widely available in the vicinities of the community. On the other hand, technological adaptations are similar to adjustments that have been studied in the agricultural technology adoption literature. At the extreme case, these types of adjustments lead to transformative adaptations. A rule of thumb to distinguish these adjustments can be to ask if they are still being systematically promoted or being diffused. Examples may include the adoption of fertilizer, irrigation technologies, pesticides, and farm machineries. While technological adaptations can benefit from the broad literature on determinants of technology adoption, non-technological adaptations can greatly benefit from further examination as a distinct group of adaptations. In this way it is ensured that all adjustments that are not technological are not overlooked.

Few studies have indicated the distinctiveness of 'non-technological adjustments'. Shikuku et al. (2017) stated that the commonly observed adaptations of changing planting dates and changing crop species/varieties in their study area in East Africa share the same characteristics of being more associated with risk-reduction. The authors argued that their wide spread use could be due to their similarity in requiring '"little investment". Kristjanson et al. (2012) using the same data set, also concluded, "many households are already adapting to changing circumstances, and their changes tend to be marginal rather than transformational in nature, with relatively little uptake of existing improved soil, water and land management practices". Similarly, Waha et al. (2013) emphasized the importance of adjustments such as changing cropping pattern and sowing date which they named "low-tech adaptation options". Non-technological adaptations, despite the fact that they not have been systematically studied, have been identified as commonly employed adaptation strategies employed by smallholder farmers in different parts of the world (Alemayehu and Bewket, 2017; Oo et al., 2017; Laux et al., 2010).

We hypothesize that the key differences between non-technological and technological adaptations are the importance of farm experience, the level of schooling, financial resources and access to extension services. When adapting to climate change using old technologies, the experience of a farmer or his land-specific human capital is instrumental (Huffman, 2001). This is because experienced farmers have the advantage of being able to perceive climate change (Maddison, 2007), and having an accumulated knowledge of old technologies used in their community. In the case of technological adaptations, only the former mechanism works, as the technology adopted is relatively new. This is particularly true in situations where experience is the main source of information on climate change adaptation, which is likely to be the case in Ethiopia (Tessema et al., 2013).

Schooling is crucial especially for adjustments that are complex to learn (Foster and Rosenzweig, 2010). Non-technological adaptation responses are, therefore, less likely to be affected by level of schooling compared to technological adaptations, which introduce technologies relatively new to farmers. This is an especially good assumption if farmers with better schooling do not benefit from better access to information, which is one benefit of schooling, on non-technological adaptation (Foster and Rosenzweig, 2010; Tan, 2014). In this case, schooling acts as a substitute to experience. Finally, since traditionally used inputs can be cheaper and more readily available, the importance of financial resources in non-technological adaptation can be minimal. Thus, variables like farm income, and access to credit have relatively reduced influence on them.

Access to extension services is directly related to access to information on various issues including climate change and new technology, and, therefore, a positive relationship is expected for both non-technological and technological adjustments. However, since the former are relatively less resource-intensive, it is expected that access to extension services will have a more pronounced effect. In the specific context of our study area in Ethiopia, while the promotion of new technologies has been at the core of the public extension system (Berhanu and Poulton, 2014; Abate et al., 2015; Abebe et al., 2013), information on climate change adaptation has been reported to be very limited (Deressa et al., 2009; Tessema et al., 2013). Therefore, the importance of access to extension services is expected to be lower for non-technological adaptations compared to technological ones in the specific setting of the study area.

There is not expected to be a major difference between non-technological and technological adaptations in their relation to family size, land size, the sex of the household head, access to market, and agroecological zone. Family and land sizes represent higher access to labor and land resources, and are likely to positively influence any adjustment. Changing planting date, however, is less likely to be associated with land size, as decision on planting date is hardly ever constrained by the availability of land. Female-headed households are known to be at a disadvantage in terms of accessing information, institutions and agricultural inputs in general due to social barriers (Wilson and Getnet, 2011). We, therefore, expect the sex of the household head to influence adjustments

Table 1
Summary of key determinants identified in the literature for changing planting date, changing crop type and adoption of irrigation (negative relationships are preceded by '–v').

Determinants	Changing planting date	Changing crop type	Irrigation
Experience/age	Oo et al. (2017), Rahut and Ali (2017), Yong (2014), Gbetibouo (2009)	Adimassu and Kessler (2016) -v Falco et al. (2011b)	Nhemachena and Hassan (2007) Gebrehiwot and Veen (2013)
Finance (income & credit)	Rahut and Ali (2017), Deressa et al. (2009)		Deressa et al. (2009) Nhemachena and Hassan (2007) Gebrehiwot and Veen (2013)
Access to extension service/ information	Rahut and Ali (2017), Yong (2014), Nhemachena and Hassan (2007), Gebrehiwot and Veen (2013), Bryan et al. (2013)	Adimassu and Kessler (2016) Nhemachena and Hassan (2007)	Yong (2014) Nhemachena and Hassan (2007)
Land size	-v Rahut and Ali (2017), Yong (2014) Alauddin and Sarker (2014) Nhemachena and Hassan (2007)	-v Tesfaye and Seifu (2016) Nhemachena and Hassan (2007)	Yong (2014) Nhemachena and Hassan (2007)
Social capital/memberships		Adimassu and Kessler (2016) -v Falco et al. (2011b)	
Access to market	Tesfaye and Seifu (2016) -v Rahut and Ali (2017)	-v Adimassu and Kessler (2016)	Nhemachena and Hassan (2007)
Family size/ labor			Shikuku et al. (2017) Nhemachena and Hassan (2007)
Education	Adimassu and Kessler (2016) Rahut and Ali (2017) Deressa et al. (2009) -v Alauddin and Sarker (2014) Gebrehiwot and Veen (2013)	-v Falco et al. (2011b)	Gebrehiwot and Veen (2013)
HH head is male	Oo et al. (2017)	Adimassu and Kessler (2016) -v Tesfaye and Seifu (2016)	
Agroecological zone	Tesfaye and Seifu (2016)	Tesfaye and Seifu (2016)	Deressa et al. (2009)

accordingly. Higher access to market can be correlated with higher access to information and better profitability of adjustments (Maddison, 2007; Foster and Rosenzweig, 2010). Therefore, market access is anticipated to invariably influence all types of adjustments. For changing planting date, however, the importance of market access is likely to be limited as it is not a type of adjustment that strongly affects cost, or type of output. The agroecological zone a farmer resides in is predicted to influence her/his adjustment decisions. Nevertheless, it is problematic to hypothesize on the nature of influence for each type of adjustment.

The main hypothesis of this study was supported by an assessment of 13 studies which considered farm-level adaptation (Table 1) concentrating on statistically significant ($\alpha = 5\%$) results for key determinants of changing planting date, changing crop type, and irrigation as adaptation responses. The first two adjustments are investigated in this study as non-technological adaptations. Access to extension services and experience are the two most frequently identified variables that positively affect changing planting date. For changing crop type, access to extension services and agroecological zone are the most influential variables. Adoption of irrigation (included in the assessment as a technological adjustments) is usually affected by income and access to credit.

3. Methods

The main objective of this study is to identify the socio-economic determinants of non-technological farm-level adaptation responses that differentiate them from technological adaptations. To this end;

1. We first identified two non-technological and two technological farm-level adaptations, and examined the degree of association of each of them to climate change based on the subjective rating of farmers.
2. We analyzed the correlation between farmers' decision to adopt the selected adaptation strategies and their socio-economic characteristics. We then interpreted the results for the non-technological in comparison to the technological ones. Whether or not a farmer adopted the adjustments was the basis for defining the dependent variables i.e., irrespective of their relation to climate change. This is because the effect of socio-economic determinants should be inferred from whether a farmer managed to adopt a particular adjustments or not, irrespective of its association to drivers. As described above in the first step, however, we first showed the importance of climate change as a driver for the selected adjustments.

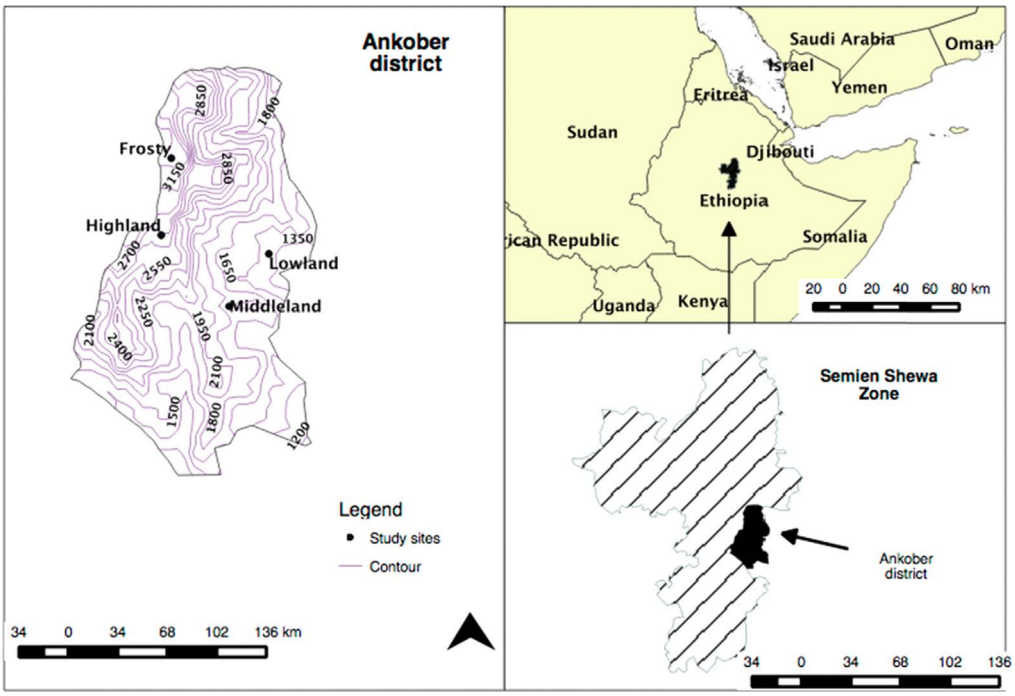

Fig. 1. Ankober district showing study sites in each of the four agroecological zones.

Our study is based on a rural household survey in the Semien Shewa Zone of Ethiopia, which is situated in the central highlands of the country (Fig. 1). Ankober Woreda (district) was purposively selected as it is characterized by typical altitudinal ranges and agricultural production systems in the Zone and in Ethiopia (Ege, 2005; Hurni, 1998; CSA, 2013). The district encompasses four major agroecological zones of the country. These are Kolla (lowland, altitude 500–1500 m a.s.l.), Woynadega (middle land, 1500–2300 m a.s.l.), Dega (highland, 2300–3200 m a.s.l.), and Wurch (frosty zone, above 3200 m a.s.l.) (Hurni, 1998). Three Kebeles (the lowest administrative unit) were purposively selected; one from Kolla, one from Weynadega, and one from Dega. We allocated a total sample size of 240 among these Kebeles approximately proportional to the share of the three agroecological zones in Semien Shewa Zone. Therefore, 50% is allocated to Kolla (lowland), 25% to Dega (middle land) and the remaining 25% to Kolla. For the Wurch (forsty zone), since its share is very low in the study area we used a sample size of 30, the minimum size recommended according to the central limit theorem. For this purpose, we used only a few villages falling in the Wurch Zones in our sampled Kebele for Dega. Hence, a total sample size of 270 was used for our study. Households in the sampled Kebeles were selected using systematic random sampling and data was collected using structured interviews.

We examined the determinants of two non-technological and two technological farm-level adaptation responses to climate change. We considered changing crop type and changing planting date as non-technological adjustments to climate change. Changing crop type occurs when a farmer adopts a new crop or drops an existing one, or does both at the same time. Changing planting date is a permanent change in the sowing time of crops to adapt to changes in climatic parameters. Changing planting date, as the name implies, is carried out using available crops and does not necessitate new technologies. Changing crop type in the study area is assumed to involve primarily crops already in use in the district or in the region. This assumption is supported by key informant interviews that included development agents in the study area. We also examined two technological farm-level adaptations to allow the interpretation of our results in relation to technological adaptations. The technological adaptations are chemical fertilizer application and rainwater harvesting. Rainwater harvesting technologies refer to the small-scale on-farm water harvesting ponds being promoted by the Ethiopian government. These adjustments were selected as they are relatively new technologies in Ethiopia which are still in the process of diffusion (Spielman et al., 2012; Awulachew et al., 2005), and therefore represent technological adaptations. To distinguish the four adjustments from coping strategies, farmers were specifically asked to mention only permanent adjustments they had made over the last 10 years.

To determine the relative importance of climate change amongst other drivers in terms of influencing adoption decisions, farmers were asked to rate (on a scale of 1–5) climate change along with other drivers for each of the four adjustments considered in our study. The other drivers were: access to agricultural extension services, land degradation, crop pests and diseases, and trends in demand or price of commodities. These drivers were selected due to their well-established significance as trends and shocks that drive livelihood strategies in Ethiopia (Shimeles and Delelegn, 2013; World Bank, 2007; PPSE, 2008; Eshte et al., 2015). To determine if there are significant differences in farmers' rating of drivers for each farm-adjustment, the Wilcoxon Signed rank test was used. We tested the null hypothesis that farmers' rating of climate change is the same as their rating of other drivers. The test was performed for each of the four adjustments.

Table 2
Description of explanatory variables and hypothesized relations.

Independent variables	Description	Hypothesized signs[a]	
		Non-technological	Technological
Farm experience of the household head in years	Continuous	+	0
Land owned in ha	Continuous	+	+
Sex of the household head	1 if female, 0 otherwise	-	-
Family size	Continuous	+	+
Walking distance from market in hours	Continuous	-	-
Level of schooling	Dummy, takes the value of zero if illiterate and one otherwise	0	+
Access to extension service	Dummy, takes the value of zero if without access and one otherwise	0	+
Farm income (excludes off-farm income)	Continuous	0	+
Access to credit	Dummy, takes the value of 0 if without access and one otherwise	0	+
Agroecological zone	Ordinal based on altitude: 0 = if Kolla, 1 = Waynadega, 2 = Dega, 3 = Wurch	No hypothesis	No hypothesis

[a] Plus and minus signs respectively indicate positive and negative correlation. Zero represents the absence (or a slight positive if any) of correlation.

A multivariate probit (MVP) model, following Greene (2003), was applied where the adoption choice of farmers (1 if adopted, 0 otherwise) was used as the dependent variable together with 10 explanatory variables (Table 2). The hypothesized relations are based on the preceding literature review. MVP is suitable for our study as it uses a multivariate distribution, which accounts for the substitutability or complementarity of choices, in our case farm-adjustments (Lin et al., 2005; Nhemachena and Hassan, 2007). This model has been successfully used in the climate adaptation literature (Nhemachena and Hassan, 2007) and in research areas with similar mulit-choice situations (e.g. Choo and Mokhtarian, 2007). The number of draws used for our study is 500 which is a safe choice for our number of equations (Cappelari and Jenkins, 2003). To check for multicollinearity problem, VIF was calculated.

4. Results

In this section, the degree of association of the selected farm-adjustments to climate change, and the results of the MVP model are presented.

4.1. The relative importance of climate change as a driver for the selected farm-level adaptations

Climate change appears to be a major driver of three of the adjustments with the exception of fertilizer use (Table 3). Climate change was rated highly as a driver for changing planting date, changing crop type, and rainwater harvesting. For changing crop type and rainwater harvesting, however, climate change was not rated significantly high in comparison to trends in demand or price and access to agricultural extension services. For fertilizer application, our result revealed that non-climatic factors are more important. Access to agricultural extension services and trends in demand seemed to drive the adoption of fertilizer use in the study area. Climate change was, however, rated higher than crop pests and diseases in determining whether fertilizer is used.

4.2. Determinants of non-technological farm-level adaptations

The MVP model was run with four dependent variables, and ten explanatory variables (Table 4). The prediction power of the model is high (Wald chi2(40) = 129.09, and Prob > chi2 = 0.0001). VIF values were all below the threshold level of 10 that verified the absence of a major multicollinearity problem. Approximately 89% of respondents adopted fertilizer and switched crops, while changing planting date took place in 87% of the farms. Contrary to these figures, rainwater harvesting was adopted only by about 20% of the respondents.

The results of the model are generally in the direction of our initial expectations. This is particularly true for three of the four key

Table 3
Wilcoxon signed-ranks test (Ho: Rating of climate change = rating for another driver).

Farm-adjustment	Z-values, (Ho: Rating of climate change = rating for each driver below)			
	Agricultural extension services	Land degradation	Crop diseases and pests	Trends in demand or price
Changing crop type	**2.339****	**10.557*****	**7.231*****	−0.734
Changing planting date	**10.312*****	**11.790*****	**11.10*****	**10.811*****
Use of fertilizer	−11.304***	−3.397***	**3.319*****	−5.891***
Rainwater harvesting	0.728	**4.014*****	**4.490*****	**3.734*****

*, ** and *** respectively indicate level of significance of 10%, 5% and 1%, and values are in bold only where climate change is rated higher.

Table 4
Results of the MVP model.

Explanatory variables	Non-technological adjustments to climate change		Technological adjustments to climate change	
	Changing crop type	Changing planting date	Fertilizer	Rainwater harvesting
Farm experience of the household head in years	−0.003	**0.017****	0.009	0.004
Land owned in ha	**0.483***	0.021	**0.697***	**0.329****
Sex	0.340	−0.295	−0.106	−0.350
Family size	0.087	0.021	**0.196****	−0.003
Walking distance from market in hours	**−0.535*****	−0.155	**−0.586*****	**−0.374*****
Level of schooling	0.127	0.047	0.459	**0.717*****
Access to extension service	−0.207	−0.322	**0.880****	−0.261
Farm income (excludes off-farm income)	0.00002	1.23 e−06	−8.90e−07	−0.00001
Access to credit	0.176	**0.421***	**0.776****	**−0.773*****
Agroecological zone	**0.302*****	0.171	**−0.895*****	**0.675*****

*, ** and *** respectively indicate level of significance of 10%, 5% and 1%, and statistically significant values are written in bold. The shaded indicate the rows we expect differences between the two categories of adaptations.

explanatory variables we expected to show the distinguishing features of non-technological adjustments: farm experience, level of schooling, and access to credit. Farm income, one of the key variables, however, did not show any statistically significant relationship with any of the adjustments. For the first three key variables, the hypothesized differences between non-technological and technological adjustments are supported by a statistically significant relationship for one of the adjustments.

Our hypothesis that farm experience had more influence on non-technological adjustments than level of schooling and access to extension services is supported by our analysis. Farm experience was positively correlated with changing planting date while the result is insignificant for changing crop type. None of the coefficients for the technological adjustments are significant for this variable. On the other hand, level of schooling has a statistically significant correlation with one of the technological adaptations; rainwater harvesting. On the premise that the public extension system in Ethiopia does not impart much climate change related information, we expected access to extension would show a relatively stronger relationship for the technological adjustments than the non-technological ones. In partial agreement with this, adoption of fertilizer is significantly associated with access to extension services.

In line with our hypotheses, socio-economic factors representing access to financial resources showed a stronger relationship to technological adjustments. Access to credit is significantly related to both technological adjustments. Contrary to our expectation, the direction of relationship is negative for rainwater harvesting. Changing planting date is also marginally related ($p < 10\%$) to farmers' access to credit. It is important to note however, that our hypotheses propose a weak relationship between non-technological adaptations and access to financial resources, rather than a complete absence of any link. Despite our expectations, farm income is not significantly correlated with any of the adjustments.

The explanatory variables we expected to have no differential influence on non-technological adjustments manifested somewhat contrasting results. Gender of the household head, walking distance from market and agroecological zone did not show any pronounced variance in their relation to the two groups of adjustments. Land size, and family size, however, showed results contrary to our expectations. Family size is associated only with fertilizer application. Land size, on the other hand, is only strongly associated with rainwater harvesting (a technological adjustment). Land size, showed a slight ($p < 10\%$) correlation with changing crop type. The unexpected relationships observed for family and land size pose a slight challenge to our positive results on the key variables. This result can be interpreted as the probability of accepting a false hypothesis, or type I error.

5. Discussion

The aim of our study is to investigate if non-technological adjustments to climate change require a distinctive set of resources compared to technological ones. Our results support that this is actually the case. Non-technological adaptations are found to be more dependent on farm-experience, and less on financial resources (access to credit) and level of schooling. Access to extension services is also shown to be less important for non-technological farm-level adaptations, possibly due to a limited amount of climate information services in the extension system of Ethiopia. Two farm-level adaptations are considered from both technological and non-technological adaptation responses. Changing crop type and changing planting date represented non-technological adjustments, whereas fertilizer application and rainwater harvesting were considered as technological. All the farm-level adaptations are initially shown to have some degree of association to climate change based on farmers' subjective rating of drivers. Our findings are supported by a statistically significant relationship found in the direction hypothesized by at least one of the farm-level adaptations.

This study is one of the first to separately examine non-technological farm-level adaptation responses as a distinct group of adaptations. However, it is possible to compare results with those of previous studies, which provided detailed results on determinants of each type of adaptation response they included. The summary of results for 13 previous studies (Table 1) support our findings, with the exception of access to extension services. In situations where extension systems deliver climate relevant information, their effect should theoretically be pronounced for non-technological adjustments. However, in the case of Ethiopia, the results are justifiable, as the extension system has been reported not to include climate related information (Deressa et al., 2009;

Tessema et al., 2013). Furthermore, evidences in the agricultural technology adoption literature support our results on farm-experience and schooling. Huffman (2001), for example, stated that in a relatively static environment (including technological environment), accumulated farm experience is more valuable than schooling.

Nevertheless, there are some inconsistencies between our original hypothesis and our results. The negative relationship between access to credit and rainwater harvesting is unexpected. It could be explained by the availability of alternative water technology which is favored if financial resources are available. Land and family size also showed an asymmetrical relationship and appear to influence technological adjustments more than non-technological ones. For changing planting date, we specifically expected no relationship with land size, which reduces the probability of showing a positive relationship for the non-technological side. In addition, it should be noted that a discrepancy for a no-relationship hypotheses is more likely to happen than a discrepancy for the type of relationship we expected for the key variables. Therefore, the results for land and family size should be considered in light of this fact.

Our study is one of the first, if not the first, to systematically investigate the difference between technological and non-technological adaptations, yet it included only two adjustments to represent each of these two categories. We also relied on a significant result for only one adaptation response each time to support our hypotheses. Further research on non-technological adaptations is therefore needed. Furthermore, it should be recognized that each type of farm-level adaptation response is unique in terms of its determinants. The goal of this study was to show general tendencies in terms of the socio-economic factors affecting non-technological adaptations.

Our findings suggest that targeting non-technological farm-level adaptations through interventions focused on experience sharing and information dissemination alone, can play an important role in reducing the impact of climate change in agriculture. Patt et al. (2005) had closely related results where they showed the strong effect of participatory workshops and climate information in non-technological adaptations. Based on a study in Zimbabwe, they demonstrated that information on seasonal forecasts, specifically when communicated in workshops, significantly improved farmers' yields particularly when their adjustments were non-technological. The lesser dependence of these types of adjustments on financial resources and level of schooling indicate that low-investment interventions are possible. This is an advantage in the context of developing countries where limited financial resources and education level often characterize smallholder farmers. Adaptation policies should ensure that the potential of non-technological adaptations is fully realized as they can represent cheap and feasible options to reduce the negative impacts of climate change. Furthermore, our findings underscore the need for a typology of farm-level adaptations that recognizes the distinctiveness of non-technological adaptation responses to climate change. This will ensure that this category of adaptations is not overlooked in development programs, which currently focus on the dissemination of new technologies.

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